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**Michiyama**

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(54) **OPTICAL SENSOR**

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(2013.01); *H04N 5/369* (2013.01)

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(58) **Field of Classification Search**  
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See application file for complete search history.

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(73) Assignee: **DENSO CORPORATION**, Kariya (JP)

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(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.

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(21) Appl. No.: **14/422,754**

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(30) **Foreign Application Priority Data**

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(57) **ABSTRACT**

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*H01L 27/144* (2006.01)

*G01S 3/783* (2006.01)

*H01L 31/02* (2006.01)

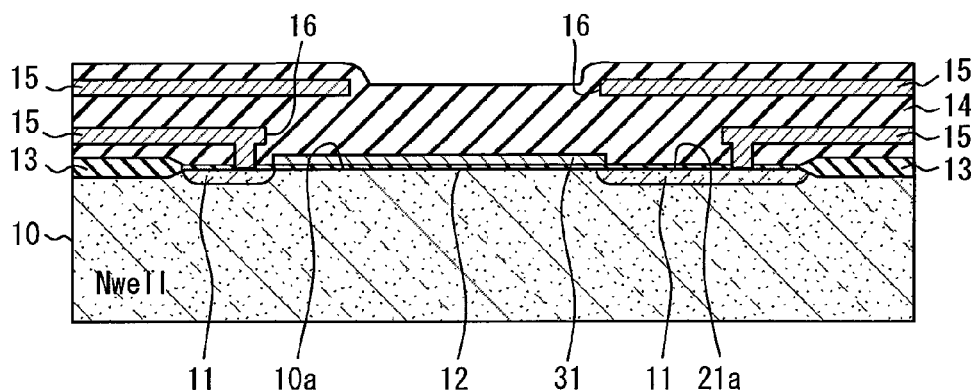
*H01L 31/0224* (2006.01)

An optical sensor has a semiconductor substrate, an insulation film formed on the semiconductor substrate, a light receiving part formed on the semiconductor substrate, and an electrode formed on the semiconductor substrate through the insulation film. The light receiving part has a light receiving element which changes light into electric charge, and a reset element which discharges the electric charge accumulated in the light receiving element. The electrode has a first electrode applying a control voltage to the reset element. The first electrode has a light shielding property. The first electrode defines a shape of a light receiving surface of the light receiving element.

(52) **U.S. Cl.**

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**3 Claims, 5 Drawing Sheets**



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FIG. 1

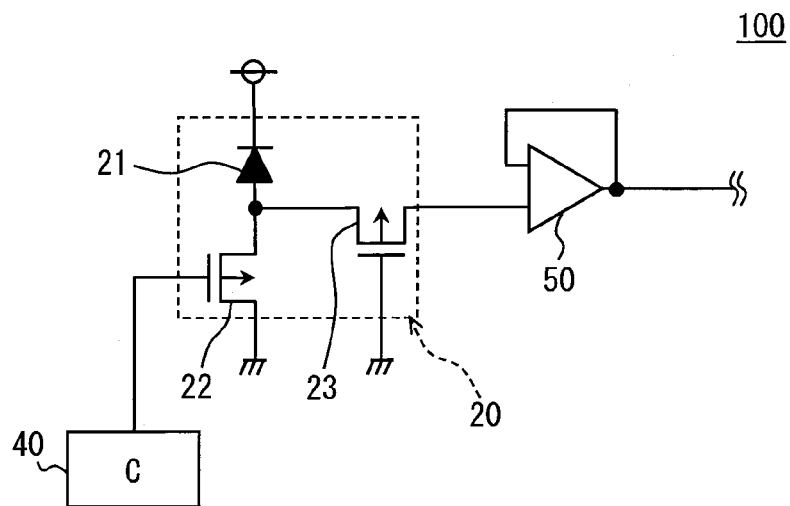
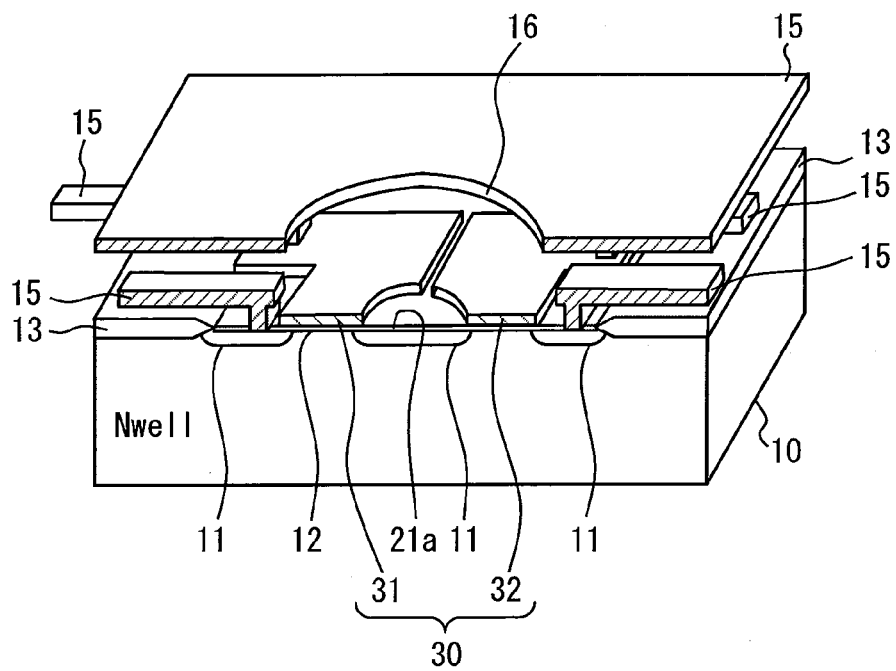
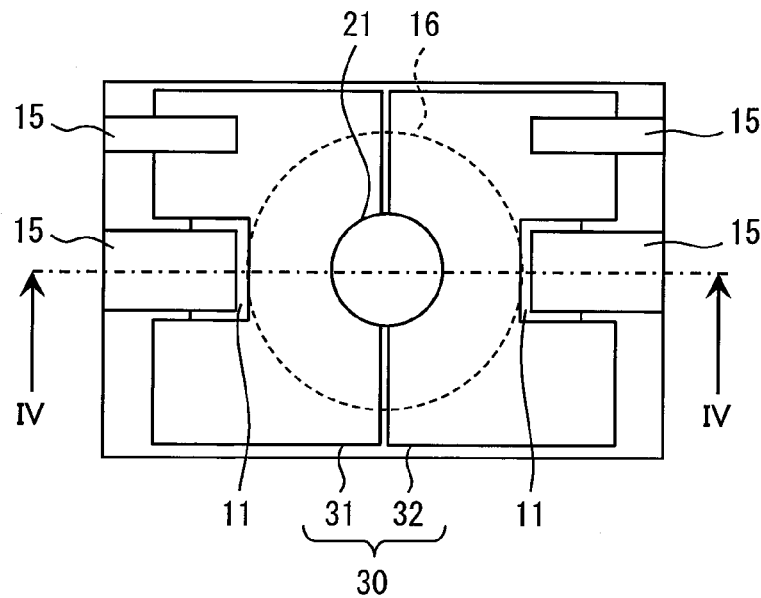


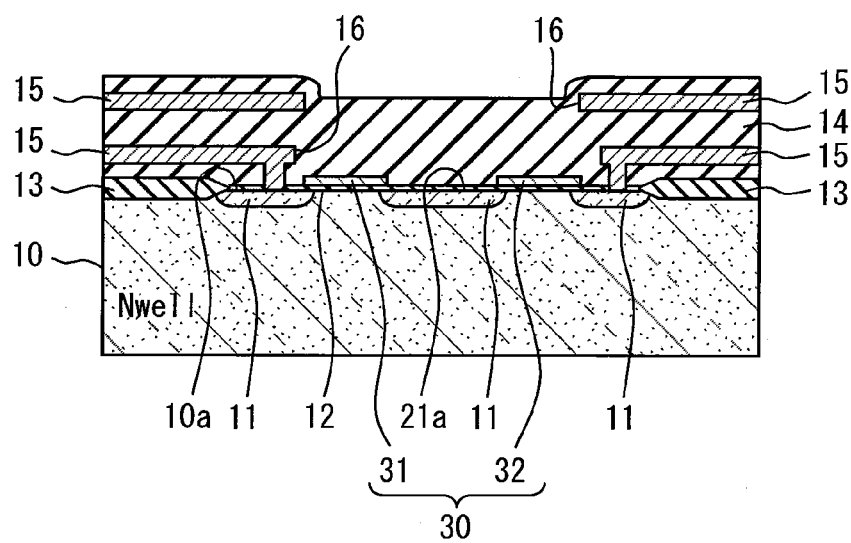
FIG. 2



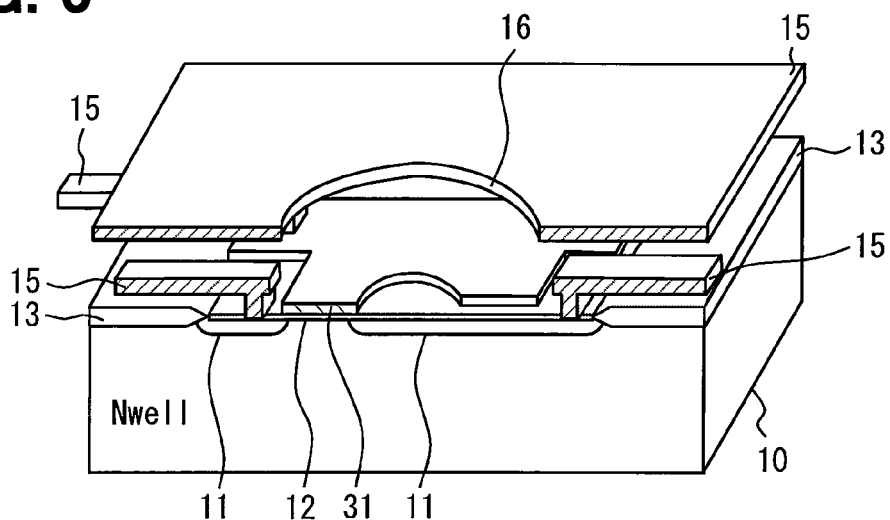
**FIG. 3**



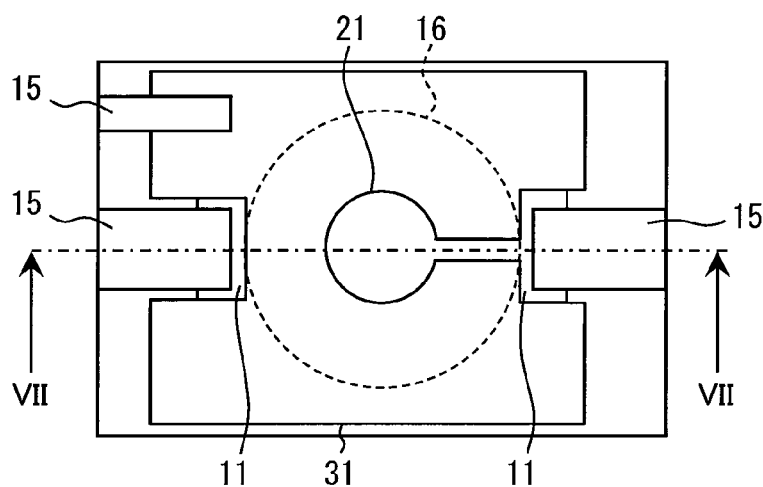
**FIG. 4**



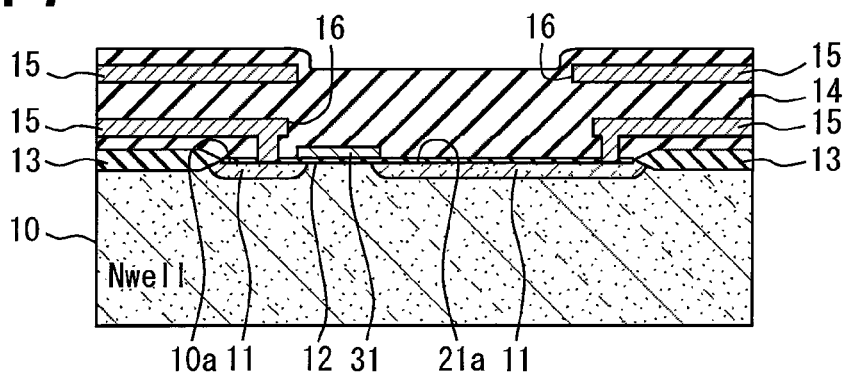
**FIG. 5**



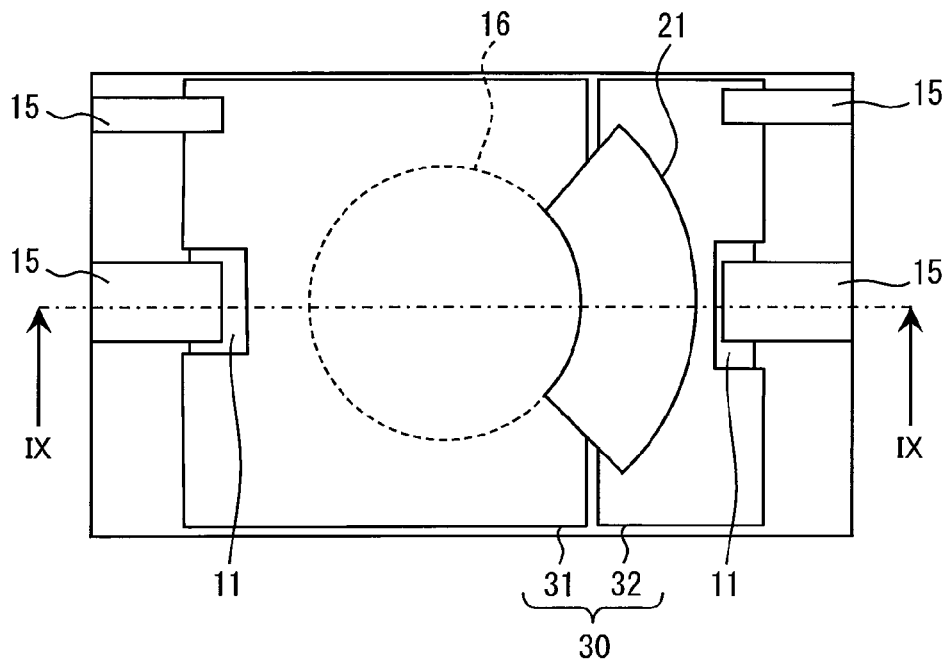
**FIG. 6**



**FIG. 7**



**FIG. 8**



**FIG. 9**

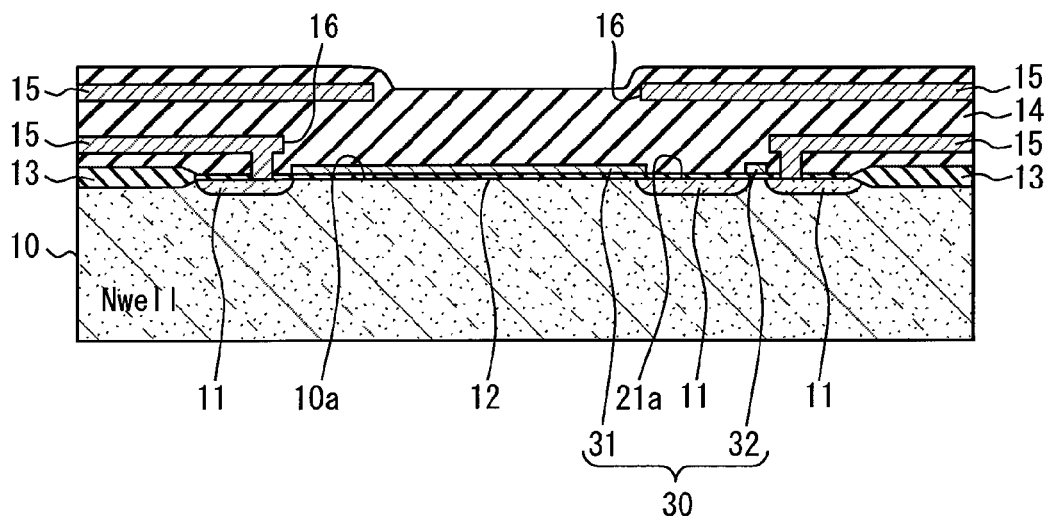


FIG. 10

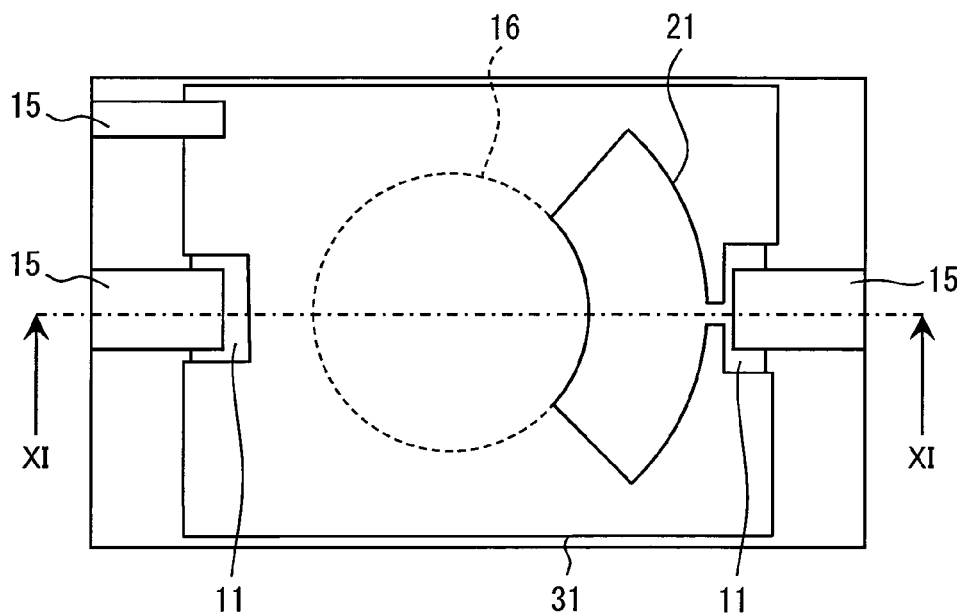
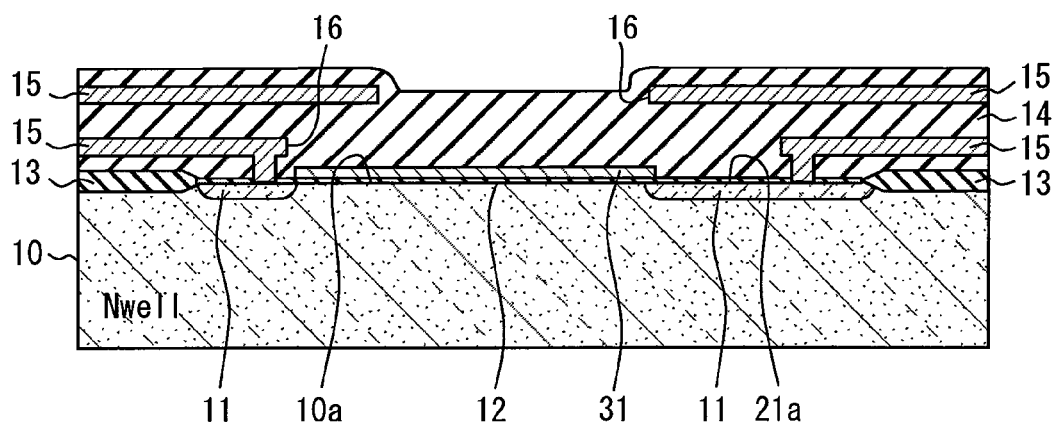


FIG. 11



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**OPTICAL SENSOR****CROSS REFERENCE TO RELATED APPLICATION**

The present disclosure is a U.S. national stage application of PCT/JP2013/006516 filed on Nov. 5, 2013 and is based on Japanese Patent Application No. 2012-274959 filed on Dec. 17, 2012, the disclosure of which is incorporated herein by reference.

**TECHNICAL FIELD**

The present disclosure relates to an optical sensor in which a light receiving part is formed on a semiconductor substrate.

**BACKGROUND ART**

Conventionally, for example, Patent Literature 1 proposes an optical sensor in which plural photo-diodes are formed on a semiconductor substrate. On the formation surface, a translucent layer having translucent property is formed. On the translucent layer, a light shielding mask having light shielding effect is formed. On the light shielding mask, plural light propagation areas are formed. In the optical sensor, an area of light incident upon a light receiving surface of the photo-diode is specified by the light propagation area of the light shielding mask.

**PRIOR ART LITERATURES****Patent Literature**

Patent Literature 1: U.S. Pat. No. 6,875,974 B

**SUMMARY OF INVENTION**

In the optical sensor shown in Patent Literature 1, two photo-diodes are arranged in a left-and-right direction as a pair, and an area of light incident upon a light receiving surface of the respective photo-diode is specified by one light propagation area located above the two photo-diodes. Therefore, when light is incident upon the optical sensor from left side, an output signal output from the right-side photo-diode becomes larger than an output signal output from the left-side photo-diode. Contrary to this, when light is incident upon the optical sensor from right side, the output signal of the left-side photo-diode becomes larger than the output signal of the right-side photo-diode. Therefore, it is possible to detect whether light is incident from the left side or the right side by comparing the output signals of the two photo-diodes.

As described above, the two photo-diodes share the one light propagation area in the optical sensor described in Patent Literature 1. This is for detecting whether light is incident from the left side or the right side. However, in order to attain this purpose, two intervals are to be secured, i.e., the interval between the left-side photo-diode and the light propagation area, and the interval between the right-side photo-diode and the light propagation area, on the semiconductor substrate. In this case, light may be incident upon a non-intended area of the semiconductor substrate, and there is a possibility that the detection accuracy of light may be lowered by electric charge produced by the light incident upon the non-intended area.

The present disclosure is aimed to provide an optical sensor in which detection accuracy of light is restricted from lowering.

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According to an aspect of the present disclosure, an optical sensor includes a semiconductor substrate having a first surface on which an insulation film is formed, a light receiving part formed in an outer layer of the first surface of the semiconductor substrate, and an electrode formed on the first surface through the insulation film. The light receiving part has a light receiving element which changes light into electric charge, and a reset element which discharges the electric charge accumulated in the light receiving element. The electrode has a first electrode that applies a control voltage to the reset element. The first electrode has a light shielding property, and a shape of a light receiving surface of the light receiving element is defined by the first electrode.

According to this, the thickness of the insulation film can be set in a manner that the control voltage can be applied to the reset element. Therefore, the distance between the electrode that has the light shielding effect and that is formed on the insulation film and the first surface of the semiconductor substrate, i.e., the formation surface of the light receiving element, can be set in a manner that the control voltage can be applied to the reset element. Therefore, light is restricted from being incident upon the non-intended area of the semiconductor substrate, compared with a configuration in which a distance is secured between the light shielding layer and the photo-diode to specify the incidence angle to the photo-diode. As a result, the detection accuracy of light is restricted from being lowered by the electric charge produced by the light incident upon the non-intended area.

Moreover, the first electrode applies the control voltage to the reset element. According to this, the number of components can be restricted from increasing and the manufacture of the optical sensor can be restricted from becoming complicated, differently from a case where the shape of light receiving surface is specified by another light shielding component that is different from a component indispensable to the reset element.

In addition, in the present disclosure, the light receiving part has an active element other than the light receiving element and the reset element. The electrode has a second electrode, other than the first electrode, that applies a control voltage to the active element. The second electrode has a light shielding property, and the shape of the light receiving surface of the light receiving element is defined by not only the first electrode but the second electrode. According to this, the shape of the first electrode is restricted from being limited. Therefore, the design of optical sensor is restricted from becoming difficult.

**BRIEF DESCRIPTION OF DRAWINGS**

FIG. 1 is a circuit diagram illustrating an outline configuration of an optical sensor according to an embodiment.

FIG. 2 is a schematic perspective view illustrating the optical sensor of the embodiment.

FIG. 3 is a schematic upper plan view illustrating the optical sensor of the embodiment.

FIG. 4 is a cross-sectional view taken along a line IV-IV of FIG. 3.

FIG. 5 is a schematic perspective view illustrating a modification of the optical sensor.

FIG. 6 is a schematic upper plan view illustrating the modification of the optical sensor.

FIG. 7 is a cross-sectional view taken along a line VII-VII of FIG. 6.

FIG. 8 is a schematic upper plan view illustrating a modification of the optical sensor.



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FIG. 9 is a cross-sectional view taken along a line IX-IX of FIG. 8.

FIG. 10 is a schematic upper plan view illustrating a modification of the optical sensor.

FIG. 11 is a cross-sectional view taken along a line XI-XI of FIG. 10.

#### DESCRIPTION OF EMBODIMENTS

An optical sensor 100 according to an embodiment is explained based on FIG. 1 to FIG. 4. In FIG. 3, an insulation film 12, a translucent film 14, and a light shielding film 15 located at the most upper layer, which are to be mentioned later, are omitted, and a dashed line represents an opening 16.

The optical sensor 100 has a semiconductor substrate 10, a light receiving part 20 formed on the semiconductor substrate 10, and an electrode 30. The light receiving part 20 has a light receiving element 21 which changes light into electric charge, and a reset element 22 which discharges the electric charge accumulated in the light receiving element 21. The light receiving element 21 further has a transmission element 23 which transmits the electric charge accumulated in the light receiving element 21. The electrode 30 has a first electrode 31 that inputs a control signal into the reset element 22, and a second electrode 32 that inputs a control voltage into the transmission element 23. Moreover, the optical sensor 100 has a control part 40 and a buffer 50 other than the above-described components 10-30. The control part 40 carries out ON/OFF control of the reset element 22, and the buffer 50 amplifies the electric charge (detection signal) of the light receiving element 21 transmitted from the transmission element 23. The transmission element 23 corresponds to an active element.

As shown in FIG. 1, the light receiving element 21 and the reset element 22 are connected in series toward a ground from a power supply source. The middle point between the elements 21 and 22 is connected to the buffer 50 through the transmission element 23. The second electrode 32 corresponding to a control electrode of the transmission element 23 is connected to the ground, and the transmission element 23 is always in ON state. Moreover, the first electrode 31 corresponding to a control electrode of the reset element 22 is connected to the output terminal of the control part 40. The reset element 22 is periodically controlled into ON state by a control signal outputted from the control part 40. Therefore, when the reset element 22 is in OFF state, the electric charge converted from light by the light receiving element 21 is accumulated in the light receiving element 21, and an electric signal according to the accumulation amount of electric charge is inputted into the buffer 50 through the transmission element 23. In contrast, when the reset element 22 is in ON state, the both-end voltage of the light receiving element 21 corresponds to the power supply voltage, and the electric charge accumulated in the light receiving element 21 is discharged.

Plural P type diffusion domains 11 that configure the light receiving part 20 are formed on the outer layer of the first surface 10a of the semiconductor substrate 10 that is Nwell domain diffused in a not-illustrated P type semiconductor substrate. The power supply source which is not illustrated is connected to the Nwell domain. The insulation film 12 and LOCOS 13 are formed on the first surface 10a, and the electrode 30 is formed on the insulation film 12. The translucent film 14 and the light shielding film 15 are layered on an area in which the electrode 30 is not formed on the insulation film 12, and LOCOS 13. The translucent film 14 is made of an electrically insulated material allowing light to pass through,

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and the light shielding film 15 is made of an electrically conductive material having light shielding properties. The opening 16 which specifies the angle of light incident upon the light receiving element 21 is defined in the light shielding film 15, and light passing through the opening 16 is incident upon the light receiving element 21.

As shown in FIG. 1 and FIG. 3, in this embodiment, two layers of the light shielding film 15 are layered on the first surface 10a through the translucent film 14. Of the two layers of the light shielding film 15, the light shielding film 15 adjacent to the first surface 10a mainly achieves the function of electrical connection with the circuit pattern (a part of the plural diffusion domains 11) formed on the semiconductor substrate 10. The light shielding film 15 located at the most upper layer away from the first surface 10a mainly achieves the function of restricting excessive light from entering the semiconductor substrate 10. The opening 16 of the light shielding film 15 located at the most upper layer has a plane circle shape, as shown in the dashed line of FIG. 3, and the angle of the incidence light incident upon the light receiving element 21 is specified and defined by the opening 16.

As described above, the light receiving part 20 has the light receiving element 21, the reset element 22, and the transmission element 23. As shown in FIG. 1, the light receiving element 21 is a photo-diode having the PN junction, in which the cathode terminal is connected to the power supply source and the anode terminal is connected to the ground through the reset element 22. Thereby, when the reset element 22 is set into the ON state, the both-end voltage of the light receiving element 21 corresponds to the power supply voltage, and the electric charge accumulated in the light receiving element 21 is discharged.

Each of the reset element 22 and the transmission element 23 is P channel type MOSFET. Therefore, when a Lo signal whose voltage level is lower than a Hi signal is inputted into the control electrode (the first electrode 31) of the reset element 22, the reset element 22 is set into ON state. Moreover, the control electrode (the second electrode 32) of the transmission element 23 is connected to the ground. Thereby, the transmission element 23 is always in ON state. Therefore, the anode electrode of the light receiving element 21 is always electrically connected with the buffer 50 through the transmission element 23.

As described above, the electrode 30 has the first electrode 31 and the second electrode 32. Each of the electrodes 31 and 32 is made of polysilicon, and a metal thin film is formed on the back surface of adhesion surface relative to the insulation film 12, so as to effect the light shielding property. Each of the elements 22 and 23 is P channel type MOSFET, and each of the electrodes 31 and 32 corresponds to the control electrode (gate electrode) of the respective elements 22 and 23. Therefore, the thickness of the insulation film 12 located between the respective electrode 31, 32 and the first surface 10a is set in a manner that it is possible to apply the control voltage to each of the elements 22 and 23. As shown in FIG. 3, the electrodes 31 and 32 have the same plane shape and are electrically independent from each other. Each of the electrodes 31 and 32 defines the shape of the light receiving surface 21a of the light receiving element 21 into a plane circle shape.

Next, the internal configuration of the light receiving element 21 is explained based on FIG. 2 to FIG. 4. As described above, the P type diffusion domain 11 constructing the main part of the light receiving part 20 is formed in the outer layer of the first surface 10a of the semiconductor substrate 10. FIG. 2 to FIG. 4 show the diffusion domain 11 in connection with the light receiving element 21. As shown in FIG. 2 and

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FIG. 4, three of the diffusion domains **11** are formed in the outer layer of the first surface **10a**. Of the three diffusion domains **11**, the photo-diode having the PN junction is constructed at the boundary between the body of the semiconductor substrate **10** and the diffusion domain **11** located directly under the opening **16** (hereafter to be referred as the first diffusion domain **11**). The other two diffusion domains **11** (i.e., the second diffusion domain **11** and the third diffusion domain **11**) correspond to a circuit pattern.

As shown in FIG. 4, the first diffusion domain **11** is distanced from the second diffusion domain **11** located on the left side by a predetermined distance. The first electrode **31** is formed through the insulation film **12** on the first surface **10a** at the position between the first diffusion domain **11** and the second diffusion domain **11**. Moreover, as shown in FIG. 3, a part of the light shielding film **15** adjacent to the first surface **10a** is electrically connected to the first electrode **31**, and is connected to the output terminal of the control part **40**. A part of the light shielding films **15** adjacent to the first surface **10a** is electrically connected to the second diffusion domain **11**, and is connected to the ground. Thereby, when the Lo signal is inputted into the first electrode **31** and when a channel is formed between the first diffusion domain **11** and the second diffusion domain **11**, the electric charge converted from light in the first diffusion domain **11** is discharged to the ground through the channel between the first diffusion domain **11** and the second diffusion domain **11**, the second diffusion domain **11**, and the light shielding film **15** connected to the second diffusion domain **11**.

As shown in FIG. 4, the first diffusion domain **11** is distanced from the third diffusion domain **11** located on the right side by a predetermined distance. The second electrode **32** is formed through the insulation film **12** on the first surface **10a** at the position between the first diffusion domain **11** and the third diffusion domain **11**. As shown in FIG. 3, a part of the light shielding film **15** adjacent to the first surface **10a** is electrically connected to the second electrode **32**, and is connected to the ground. A part of the light shielding film **15** adjacent to the first surface **10a** is electrically connected to the third diffusion domain **11**, and is connected to the transmission element **23**. Thereby, a channel is always formed between the first diffusion domain **11** and the third diffusion domain **11**, which are always electrically connected with each other. Therefore, the electric charge converted from light in the first diffusion domain **11** is transmitted to the buffer **50** through the channel between the first diffusion domain **11** and the third diffusion domain **11**, the third diffusion domain **11**, and the light shielding film **15** connected to the third diffusion domain **11**.

Next, operation and effect of the optical sensor **100** of the embodiment is explained. As described above, the plane shape of the light receiving surface **21a** of the light receiving element **21** is defined by each of the first electrode **31** corresponding to the control electrode of the reset element **22** and the second electrode **32** corresponding to the control electrode of the transmission element **23**. The thickness of the insulation film **12** located between the electrode **31**, **32** and the first surface **10a** is set in a manner that it is possible to apply the control voltage to each of the elements **22** and **23**. Therefore, light is restricted from entering the not-intended domain of the semiconductor substrate **10** compared with a configuration in which a predetermined distance is secured between a light shielding layer and a photo-diode in order to specify the incidence angle relative to a photo-diode. As a result, the detection accuracy of light can be restricted from being lowered by the electric charge produced by the light which is unintentionally introduced.

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The first electrode **31** applies the control voltage to the reset element **22**, and the second electrode **32** applies the control voltage to the transmission element **23**. According to this, the number of components can be restricted from increasing and the manufacture of the optical sensor **100** can be restricted from becoming complicated, compared with a configuration in which the plane shape of the light receiving surface **21a** is specified by another light shielding component that is different from a component indispensable to the reset element **22** and the transmission element **23**.

Because the first electrode **31** and the second electrode **32** define the plane shape of the light receiving surface **21a**, the shape of the first electrode **31** (the second electrode **32**) is less limited. Therefore, the design of the optical sensor **100** can be restricted from becoming difficult.

The present disclosure is not limited to the above mentioned embodiment, and may be modified in a range not deviated from the scope of the present disclosure so as to be implemented.

In this embodiment, each of the electrodes **31** and **32** defines the plane shape of the light receiving surface **21a**. However, as shown in FIG. 5 to FIG. 7, the plane shape of the light receiving surface **21a** may be defined only by the first electrode **31**.

In this embodiment, each of the electrodes **31** and **32** defines the plane shape of the light receiving surface **21a** into the circle shape. However, as shown in FIG. 8 to FIG. 11, the plane shape of the light receiving surface **21a** may be defined into an arc state. Also in this configuration, as shown in FIG. 10 and FIG. 11, the plane shape of the light receiving surface **21a** may be specified only by the first electrode **31**.

In this embodiment, the plane shape of the light receiving surface **21a** of one light receiving element **21** is specified by the electrodes **31** and **32** respectively corresponding to the control electrodes of the reset element **22** and the transmission element **23** that correspond to the one light receiving element **21**. However, although not illustrated, the plane shape of the light receiving surface **21a** of one light receiving element **21** may be specified by the electrodes **31** and **32** respectively corresponding to the control electrodes of the reset element **22** and the transmission element **23** that correspond to plural light receiving elements **21**.

In this embodiment, the conductivity type of the semiconductor substrate **10** is N type. However, the conductivity type of the semiconductor substrate **10** is not limited to the above-mentioned example, but P type may also be adopted. In this case, the diffusion domain **11** is N type, and each of the reset element **22** and the transmission element **23** is N channel type MOSFET. Moreover, the reset element **22** and the light receiving element **21** are connected in series toward the ground from the power supply source, and the second electrode **32** is connected to the power supply source.

In this embodiment, each of the reset element **22** and the transmission element **23** is MOSFET. However, the reset element **22** and the transmission element **23** are not limited to the above-mentioned example, and may be voltage control type transistor.

In this embodiment, of the three diffusion domains **11** constructing the main component of the light receiving part **20**, each of the second diffusion domain **11** located on the left side and the third diffusion domain **11** located on the right side is a circuit pattern. However, the second diffusion domain **11** may be a part of components of the reset element **22**, and the third diffusion domain **11** may be a part of components of the transmission element **23**.

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The invention claimed is:

**1.** An optical sensor comprising:

a semiconductor substrate having a first surface on which an insulation film is formed;

a light receiving part formed in an outer layer of the first surface of the semiconductor substrate; and

an electrode formed on the first surface through the insulation film, wherein:

the light receiving part has a light receiving element which changes light into electric charge, and a reset element which discharges the electric charge accumulated in the light receiving element,

the electrode has a first electrode that applies a control voltage to the reset element,

the first electrode has a light shielding property,

a shape of a light receiving surface of the light receiving element is defined by the first electrode,

the semiconductor substrate is a first conductivity type,

a plurality of diffusion layers is formed in an outer layer of the first surface of the semiconductor substrate, the plurality of diffusion layers being a second conductivity type different from the first conductivity type,

at least one of the plurality of diffusion layers forms the light receiving element, and at least one of the plurality of diffusion layers forms a circuit pattern,

the diffusion layer forming the light receiving element and the diffusion layer forming the circuit pattern are dis-

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tanced from each other by a predetermined distance, and a part of the electrode is located on the first surface between the diffusion layer forming the light receiving element and the diffusion layer forming the circuit pattern, and

when a control voltage is applied to the electrode, a channel is formed between the diffusion layer forming the light receiving element and the diffusion layer forming the circuit pattern, and the diffusion layer forming the light receiving element and the diffusion layer forming the circuit pattern are electrically connected.

**2.** The optical sensor according to claim 1, wherein:

the light receiving part further has an active element,

the electrode further has a second electrode that applies a control voltage to the active element,

the second electrode has a light shielding property, and

the shape of the light receiving surface of the light receiving element is defined also by the second electrode.

**3.** The optical sensor according to claim 1, wherein:

a light shielding film is layered on the first surface of the semiconductor substrate through a translucent film,

an opening is formed in the light shielding film, and

the opening defines an angle of incidence light which is incident upon the light receiving surface of the light receiving element.

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